Fabrication and Characterization of Activated Carbon from 'Aking rice' Waste

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Abstract

Rice as a staple food for most Indonesian people contributes a high amount of food waste. Indonesian people generally process cooked rice waste into 'Aking rice'. 'Aking rice' is a result from the drying of cooked rice with the sun. 'Aking rice' is generally used as animal feed, but on the other hand, aking rice has the potential to be used as a source of activated carbon because it contains high carbon. We learn the optimum carbonization temperature for making activated carbon from aking rice by conducting several characterization tests on activated charcoal from each carbonization temperature. The fabrication method of activated carbon in this research occurs in two steps, carbonization first followed by chemical activation using HCl. The carbonization temperature variations are 300°C, 400°C, and 500°C. The optimum carbonization temperature is 500°C because all results comply with requirement. Activated carbon from carbonization temperature at 500°C has water content of 0,96%, ash content of 0,98%, volatile matter content of 19,30%, and fixed carbon content 79,72%. Variation of carbonization temperature does not give significant effect for ash content and water content, but give significant effect for volatile matter content and fixed carbon content.

Keywords: 'Aking Rice', Activated Carbon, Characterization

1. Introduction

Rice is the biggest food commodity in Indonesia because it is use for daily consumption of Indonesian people. In 2020 total rice consumption reach 94,02 kg per capita and in 2023 predicted reach 92,20 kg per capita (Kementerian Pertanian Republik Indonesia, 2021). Rice as a staple food for most Indonesian people contributes a high amount of food waste. In 2022 as much as 41% of waste in Indonesia were came from food waste (Kementerian Lingkungan Hidup dan Kehutanan, 2022), one of them is cooked rice waste. Indonesian people generally process cooked rice waste into 'Aking rice'. 'Aking rice' is a result from the drying of cooked rice with the sun and generally used as animal feed (Zulfikar et al. 2014). In addition, 'Aking rice' has also been investigated for its ability to be synthesized into biodegradable plastics and bioethanol (Setyawati et al. 2020; Widyastanti and Widyaningrum 2022).

On the other hand, 'Aking rice' has the potential to be used as a source of activated carbon or activated charcoal because it contains high carbon. The source of carbon content in 'Aking rice' comes from the carbohydrate component. The content of carbohydrate in 'Aking rice' is 83,14% (Setyawati et al. 2020).

Table 1. Previous research on the utilization of "Aking rice"

Types of products resulting from the utilization of "Aking rice"	Research Results	References
Biodegradable Plastic	Plastic is produced which can be degraded 100% within 14 days, with plastic properties having a tensile strength value of 6.9 N, and 19.85% elongation.	(Setyawati et al. 2020)
Bioethanol	Bioethanol Concentration of crude amylase enzyme Bacillus amyloliquefaciens affects the sugar and ethanol content of fermented rice aking using Zymomonas mobilis.	(Widyastanti and Widyaningrum 2022)
Animal feed	The use of aking rice flour as a substitute for bran can increase the percentage of carcass but does not increase the percentage of deposition of breast meat, percentage of abdominal fat and leg color.	(Zulfikar et al. 2014)

Activated carbon is an adsorbent that is widely used in reducing contaminant levels in various types of wastewater because its structure has many pores that can absorb contaminants. Activated carbon is a material in the form of amorphous carbon which has a very large surface area of 300-2000 m^2/gram (Dahlan, Siregar, and Yusra 2013).

Table 2. The component of 'Aking rice'

Component	Percentage (%)
Carbohydrate	83,14
Amylose	29,70
Protein	3,36

The difference between ordinary charcoal and activated carbon is that ordinary charcoal is the result of combustion in the form of charcoal which still contains hydrocarbons, while activated carbon is carried out in the process of removing the hydrocarbons produced during combustion by dehydration using acids, bases, and salts such as HCl, H_2SO_4, NaOH, $ZnCl_2$, NaCl and $CaCl_2$. In this research using HCl as an Activator because Hydrochloric Acid (HCl) has been widely used as an activator (activator) in activated carbon (Setyaningrum, 2018).

Before being activated, the raw material must go through a carbonization process. Carbonization is the process of breaking down cellulose into carbon at temperatures around 275ºC (Zhong et al. 2012). The results of previous research by (Hanum, Bani, and Wirani 2017) showed that carbonization of Rice Husk at a temperature of 400-600°C gave high fixed carbon content (42,02%-49,33%) with optimum condition of carbonization obtained at temperature of 500°C and time of 150 minutes with moisture content of 4,86%, ash content of 30,04%, volatile matter content of 15,76% and fixed carbon content of 49,33%. Therefore, in this research the carbonization temperature used varies between 300-500°C to obtain the most optimum carbonization temperature for the manufacture of activated carbon from aking rice. This research will study the optimum carbonization temperature for making activated carbon from aking rice by conducting several characterization tests on activated charcoal from each carbonization temperature. The characterization tests are water content, ash content, volatile matter content, and fixed carbon content. The result of this characterization test will be evaluated by comparing the results with requirement for technical grade activated carbon SNI 06-3730-1995. Powdered activated charcoal with good quality has maximum water content is 15%, maximum volatile matter content is 25%, maximum ash content is 10% and minimum carbon content is 65% (SNI 06-3730 1995).

2. Research Method

This research consists of 3 main steps. There are carbonization process, activation process and characterization test. The carbonization and activation process follows the previous procedure for making activated carbon from rice husk by (Hanum et al. 2017) which has been modified. The first step is carbonization of 'Aking rice to produce charcoal. Carbonization carries out with variations in the temperature of carbonization (300°C, 400°C and 500°C) in electric retort. The electric retort that has been filled with aking rice (about 3-4 kg of 'Aking rice is needed) is heated gradually from ambient temperature to each carbonization temperature setpoint, and after the temperature is reached the electric retort is turned off. After the electric retort not hot, the charcoal from 'Aking rice' is removed and yield percentage of charcoal is calculated.

Figure 1. Electric retort for carbonization process

The second stage is activation process of charcoal to produce activated carbon. The activation process is carried out by shaking the charcoal with 5% hydrochloric acid (HCl) solution (ratio of charcoal with HCl is 1:10) for 24 hours on horizontal shaker at 200 rpm. This process will produce charcoal slurry. The charcoal slurry was filtered with filter paper to get solid residue. The residue is washed by aquadest until the filtrate reaches neutral pH. Neutral solid residue then dried in oven at 110°C. The dried residue is activated carbon which is ready to carry out characterization test.

The last step is characterization test. The characterization tests are water content, ash content, volatile matter content, and fixed carbon content. The characterization test is carried out by following procedure in SNI 06-3730-1995. All the tests carry out in three replicates. The result of characterization test was then analyzed by ANOVA statistic test at 95% confidence interval to determine whether the result from each carbonization temperature gives a significant difference.

3. Results and Discussions

The result of characterization test indicates that at carbonization temperature of 500°C is optimum because all the result complies with requirement in SNI 06-3730-1995 for powdered activated carbon.

Table 3. Result of characterization test

No	Parameters	300°C	400°C	500°C	Requirement*
1	Yield of charcoal	50,49%	33,17%	37,66%	-
2	Water content	0,98 ± 0,05%	0,94 ± 0,04%	0,96 ± 0,05%	Maximum 15%
3	Ash content	0,92 ± 0,05%	0,95 ± 0,03%	0,98 ± 0,06%	Maximum 10%
4	Volatile matter content	44,85 ± 1,21%	27,53 ± 0,94%	19,30 ± 0,91%	Maximum 25%
5	Fixed carboncontent	54,23 ± 1,19%	71,51 ± 0,91%	79,72 ± 0,86%	Minimum 65%

*Requirement according to SNI 06-3730-1995

The result of characterization test indicates that at carbonization temperature of 500°C is optimum because all the result complies with requirement in SNI 06-3730-1995 for powdered activated carbon. According to table 3 with increasing of carbonization temperature will decrease the yield percentage of charcoal and volatile matter content, increase the fixed carbon content, and does not have a significant effect on moisture content and ash content.

Table 4. Result of ANOVA test

		Sum of squares	df	Mean square	F	Sig.
water content	Between Groups	.002	2	.001	.489	.635
	Within Groups	.012	6	.002		
	Total	.014	8			
ash content	Between Groups	.005	2	.003	1.312	.337
	Within Groups	.012	6	.002		
	Total	.017	8			
volatile matter content	Between Groups	1020.131	2	510.065	481.519	.000
	Within Groups	6.356	6	1.059		
	Total	1026.487	8			
fixed carbon content	Between Groups	1015.620	2	507.810	509.145	.000
	Within Groups	5.984	6	.997		

According to ANOVA test result at table 4, the significant value (Sig.) of water content and ash content are above 0.05 which means the carbonization temperature does not have a significant effect for this parameter. For ash and volatile matter content, the significant value is below 0.05 which means the carbonization temperature have a significant effect for this parameter and it can be proven by Tukey test result at table 5 and table 6 that showed for each carbonization temperature gives a significant effect between each other for this parameter.

Table 5. Volatile matter's tukey test result

Carbonization temperature	N	Subset for alpha = 0.05		
		1	2	3
500	3	19.3000		
400	3		27.5343	
300	3			44.8464
Sig.		1.000	1.000	1.000

Table 6. Fixed carbon's tukey test result

Carbonization temperature	N	Subset for alpha = 0.05		
		1	2	3
300	3	54.2313		
400	3		71.5140	
500	3			79.7187
Sig.		1.000	1.000	1.000

All results of water and ash content comply with the requirement in SNI 06-3730-1995. Moisture content is the amount of water in samples. Determination of moisture content aims to determine the hygroscopic properties of carbon (Siahaan, Hutapea, and Hasibuan 2013). Ash content is used to determine the quality of activated carbon. Ash content refers to residual minerals in activated carbon after carbonization and activation process (Anisuzzaman et al. 2015). The presence of ash leads to blockage of the pores which reduces the surface area of activated carbon (Siahaan et al. 2013).

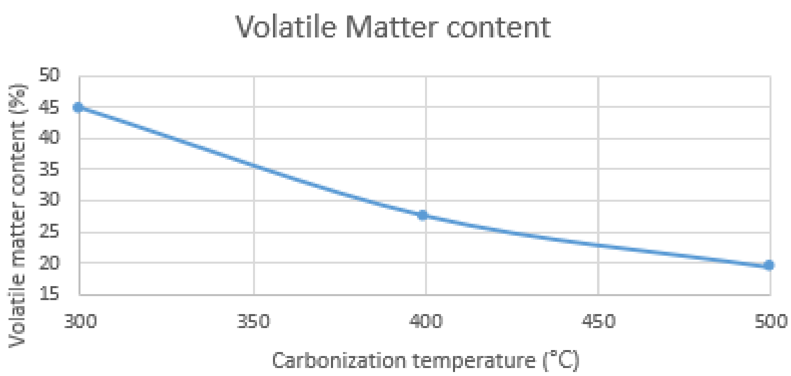

Figure 2. Effect of Carbonization Temperature on volatile matter content

The amount of volatile matter corresponds to compounds that have not evaporated during carbonization, but evaporates at 950 °C (Siahaan et al. 2013). As in Fig. 2, it can be observed that volatile matter content tends to decrease with the increase of carbonization temperature. The result is consistent with that obtained by (Hanum et al. 2017) which increasing the carbonization temperature decrease the levels of volatile matter. In this research, the lowest volatile matter content at carbonization temperature of 500°C.

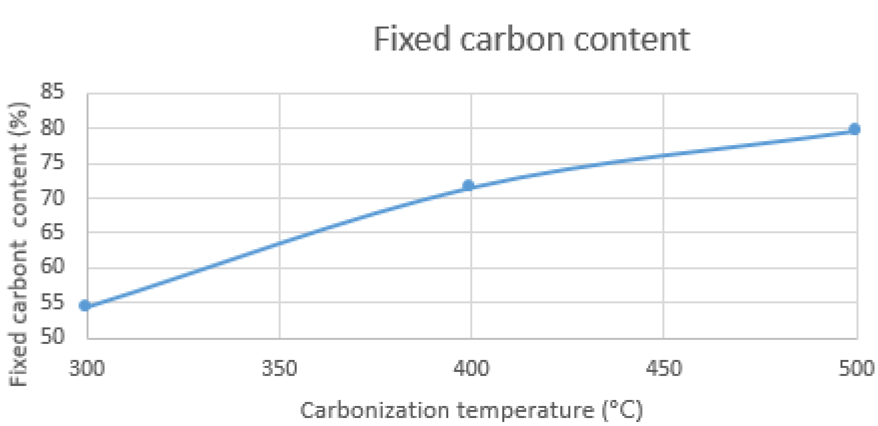

Figure 3. Effect of Carbonization Temperature on fixed carbon content

The higher the fixed carbon content, the greater the surface area of activated carbon so that it can increase its adsorption capacity. The fixed carbon content is obtained from the difference between the total material and the moisture content, ash content and volatile matter content remaining in the material (Kurniasih, Pratiwi, dan Amin 2021). In this research, the biggest fixed carbon content at carbonization temperature of 500°C.

4. Conclusions

Fabrication of activated carbon from 'Aking rice' waste by variation of the carbonization temperature between 300°C until 500°C following by chemical activation using hydrochloric acid gives optimum carbonization temperature at 500°C with water content of 0,96%, ash content of 0,98%, volatile matter content of 19,30%, and fixed carbon content 79,72%. Variation of carbonization temperature does not give significant effect for ash content and water content but gives significant effect for volatile matter content and fixed carbon content.

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